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(54) **SUBSTRATE TRANSFER SYSTEM AND SUBSTRATE PROCESSING SYSTEM**

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(52) **U.S. Cl.**
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(58) **Field of Classification Search**
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USPC 414/226.05, 217
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(57) **ABSTRACT**

A substrate transfer system includes a substrate transfer robot disposed in a robot installment area defined between a first apparatus and a second apparatus comprising an opening. The substrate transfer robot includes a hand and an arm. The hand is configured to support a substrate. The arm is configured to move the hand. The arm and the hand supporting the substrate are configured to rotate on a horizontal surface within a minimal rotation area of the substrate transfer robot such that an outer periphery of the minimal rotation area overlaps an inside of the second apparatus through the opening so as to transfer the substrate from a first position in the first apparatus to a second position in the second apparatus through the opening.

44 Claims, 10 Drawing Sheets

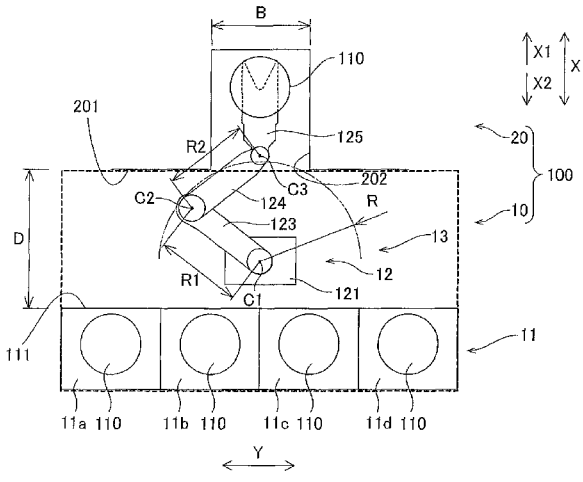

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FIG. 1

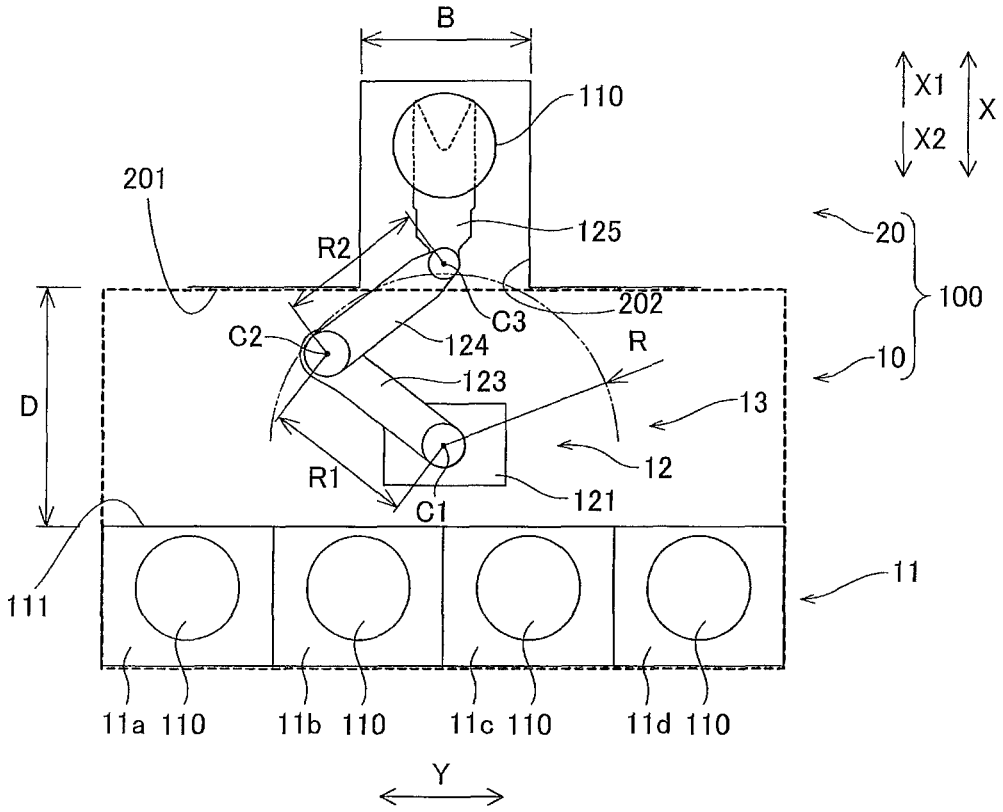
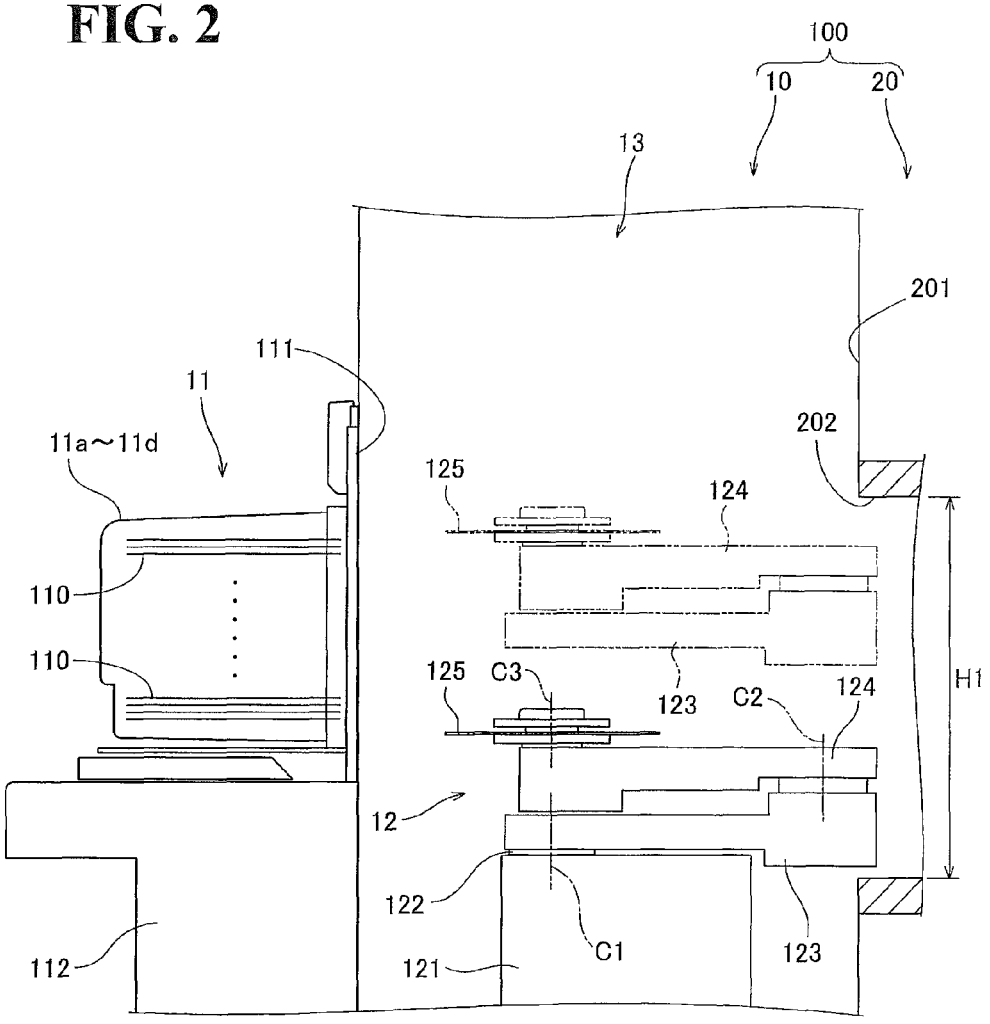

B
110
X1
X2
X
201
125
20
R2
202
100
C3
C2
124
R
10
123
D
13
12
R1
C1
121
111
11
11a 110
11b 110
11c 110
11d 110
Y

FIG. 2


100
10
20
13
201
111
11
11a~11d
202
125
124
110
110
125
C3
123
C2
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12
122
C1
123
112
121

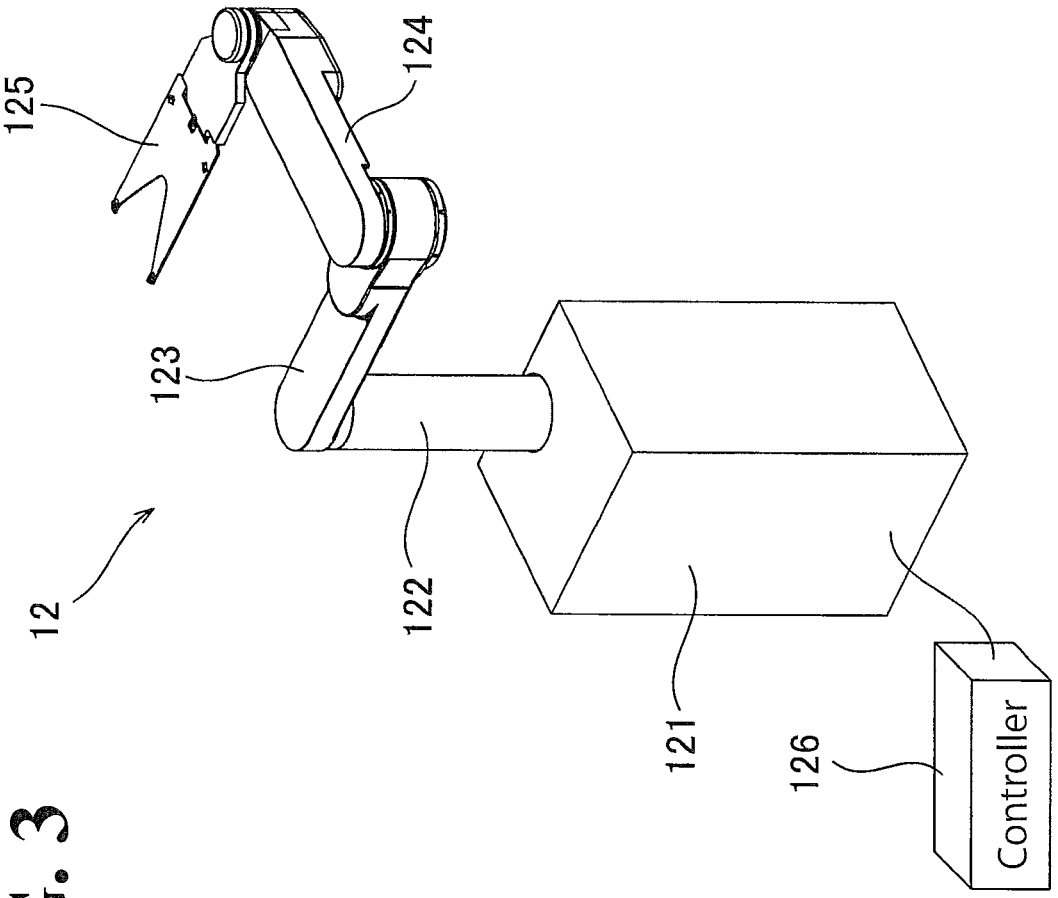


FIG. 3

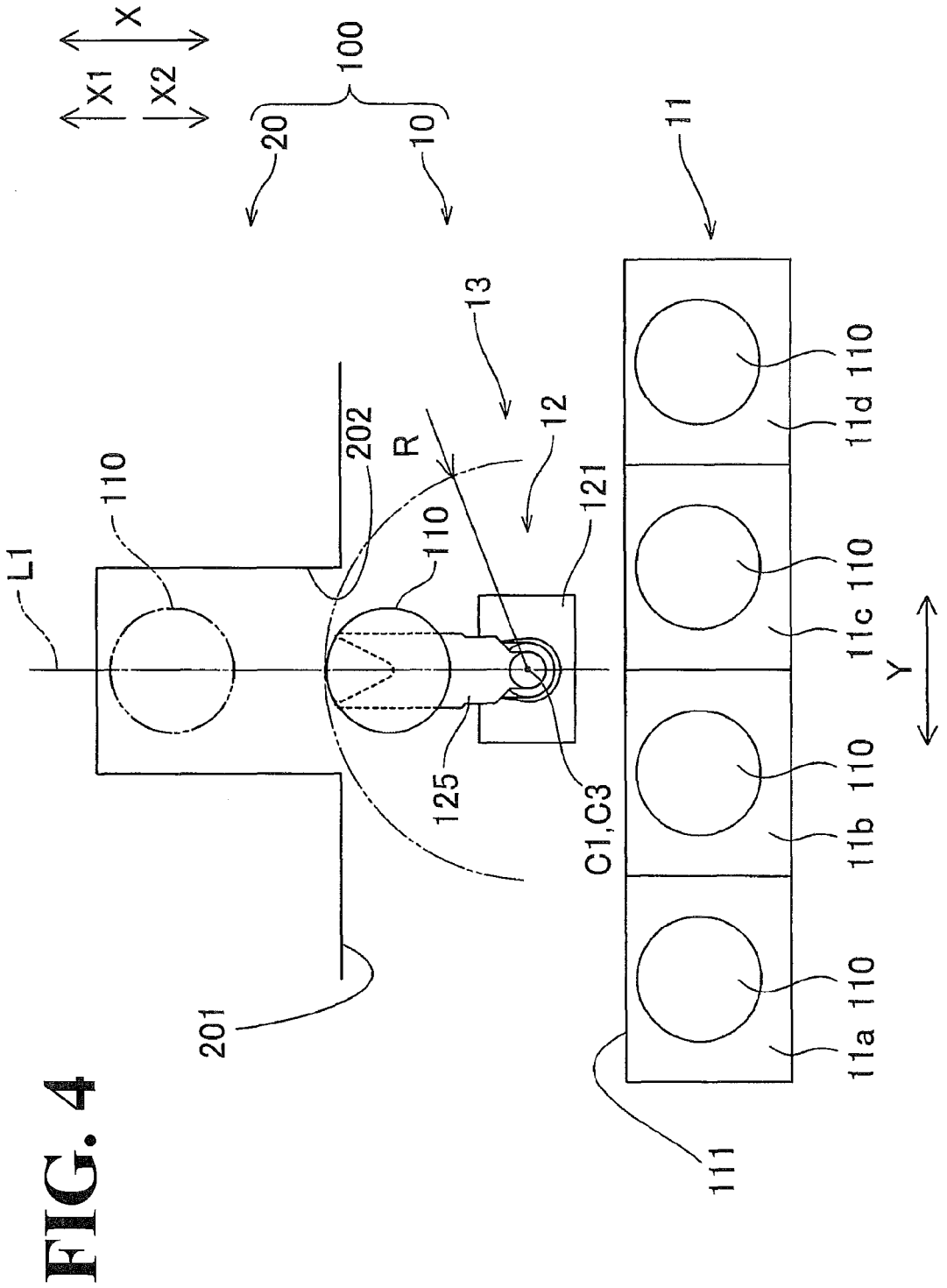

X
X1
X2
100
20
10
11
13
12
121
202
R
110
L1
125
C1,C3
201
111
11a 110
11b 110
11c 110
11d 110
Y

FIG. 4

FIG. 5

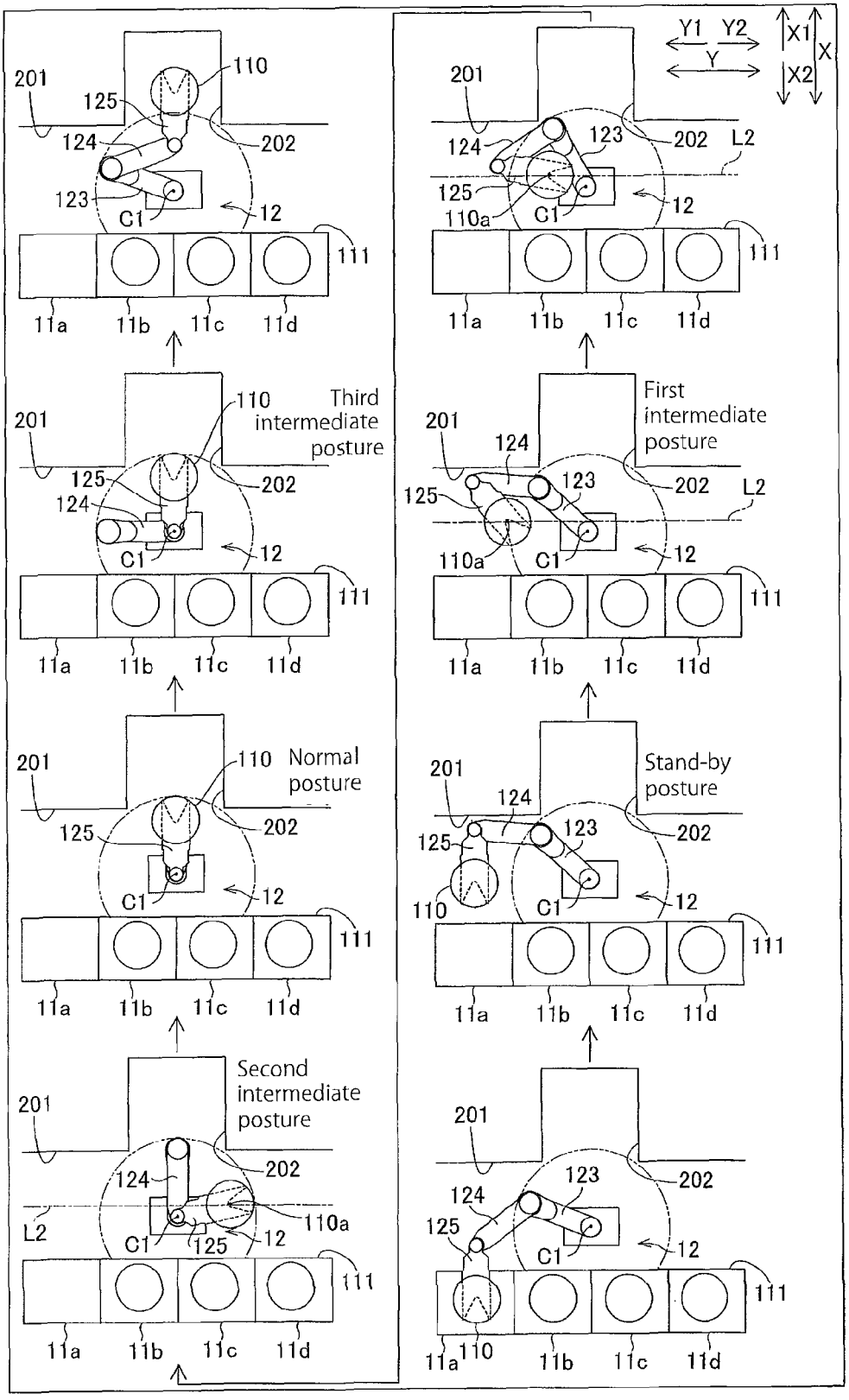

Y1
Y2
Y
X1
X2
X
201
110
125
124
202
123
C1
12
111
11a
11b
11c
11d
Third intermediate posture
Normal posture
Second intermediate posture
First intermediate posture
Stand-by posture
L2
110a

FIG. 6

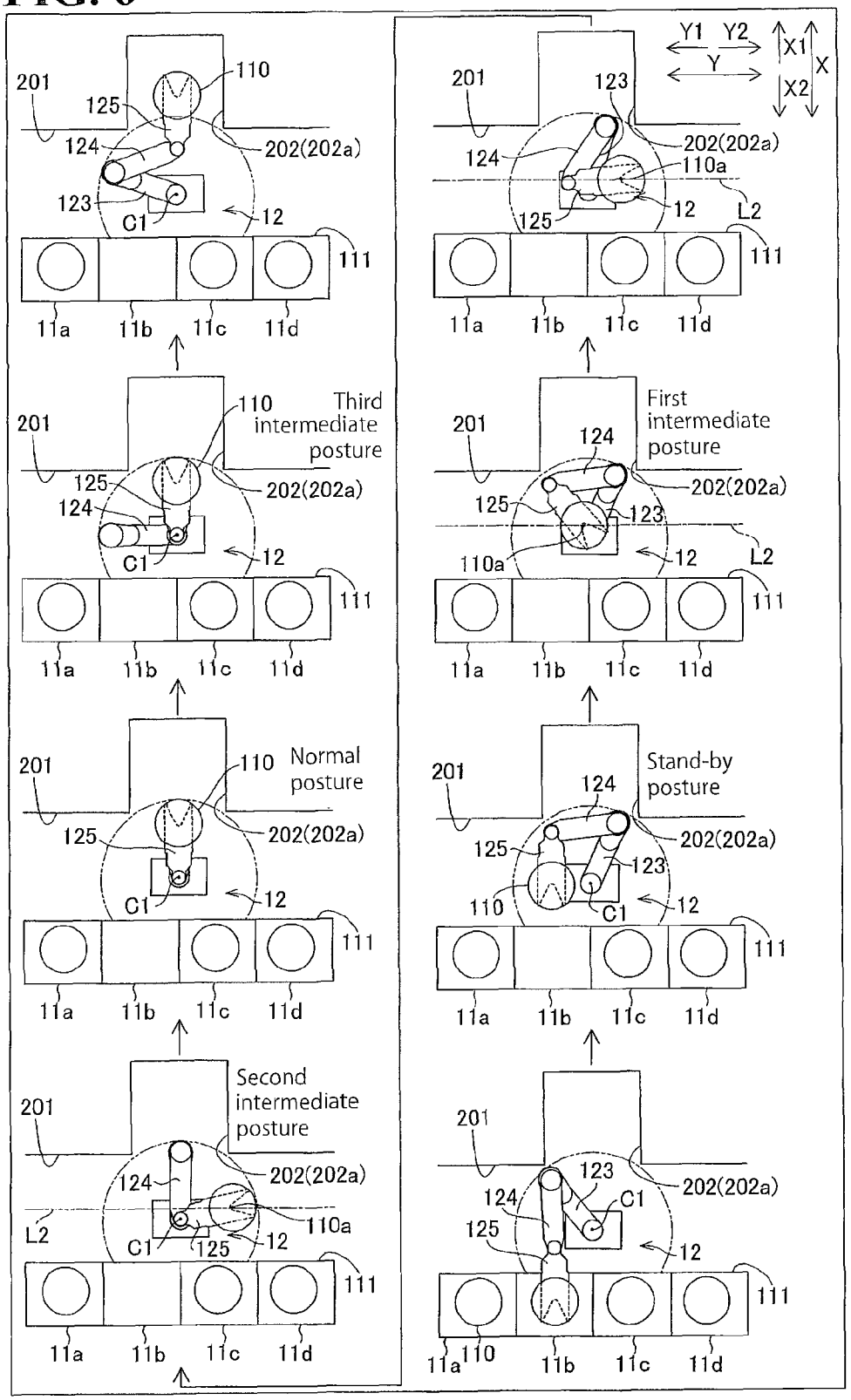
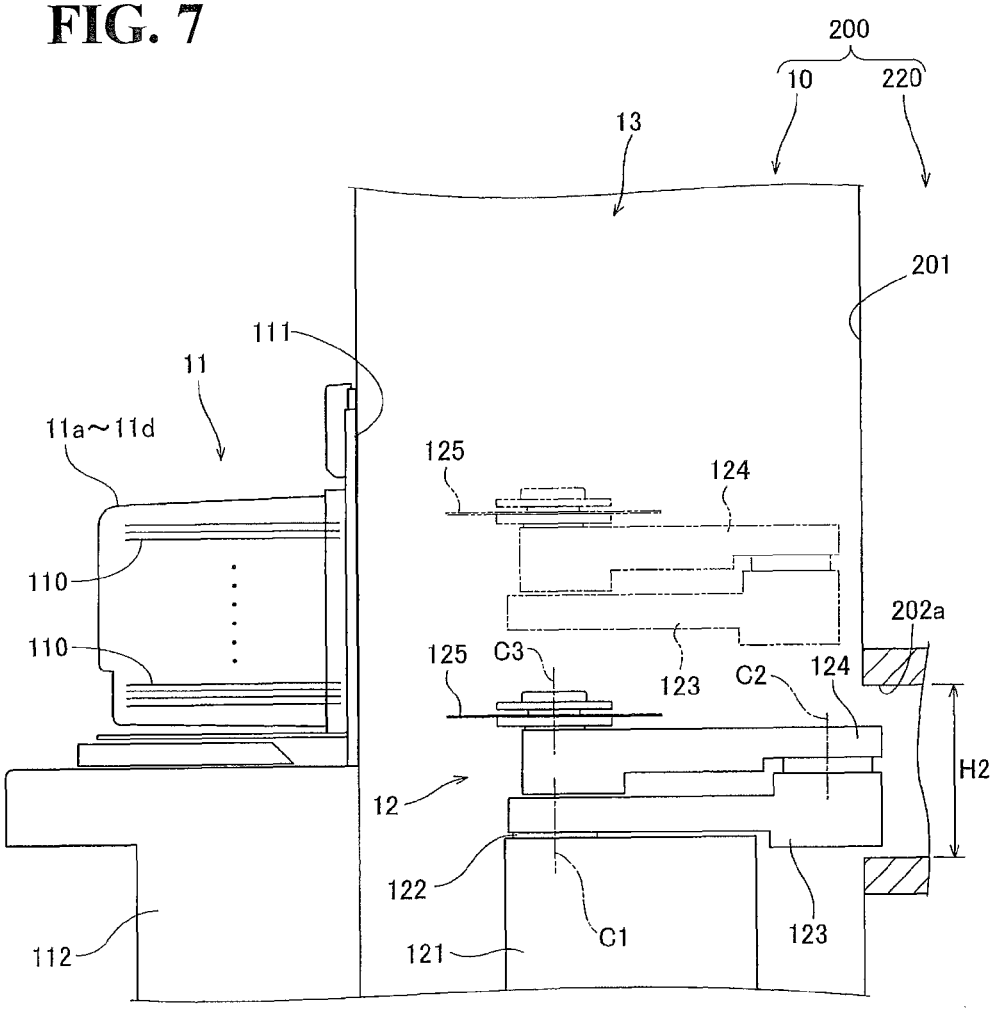

201
110
125
124
202(202a)
123
C1
12
111
11a
11b
11c
11d
Third intermediate posture
Normal posture
Second intermediate posture
First intermediate posture
Stand-by posture
Y1
Y2
Y
X1
X2
X
110a
L2

FIG. 7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10
220
13
201
111
11
11a~11d
125
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202a
125
C3
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C2
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12
122
C1
123
112
121

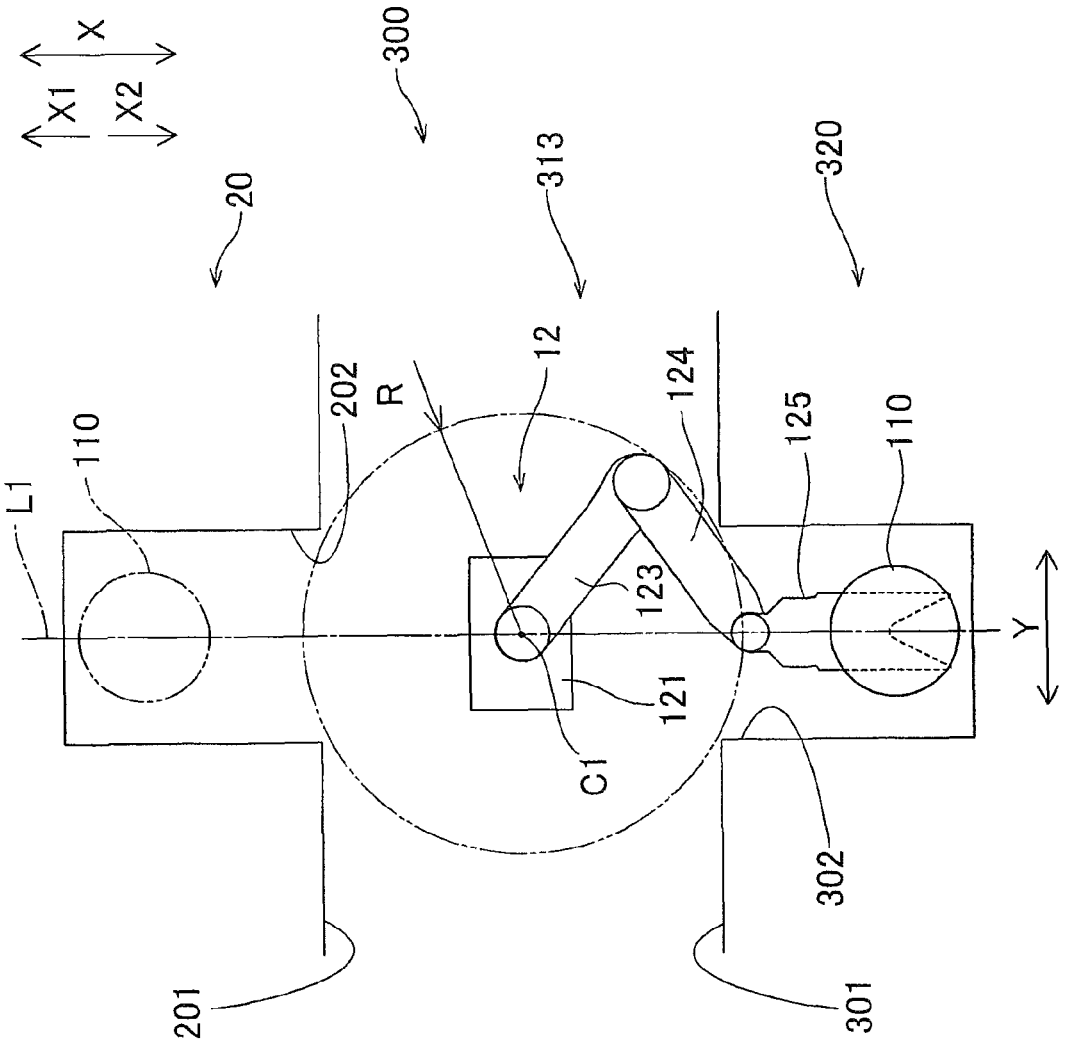

X
X1
X2
300
20
313
320
12
202
R
124
125
110
110
L1
123
Y
121
C1
302
201
301

FIG. 8

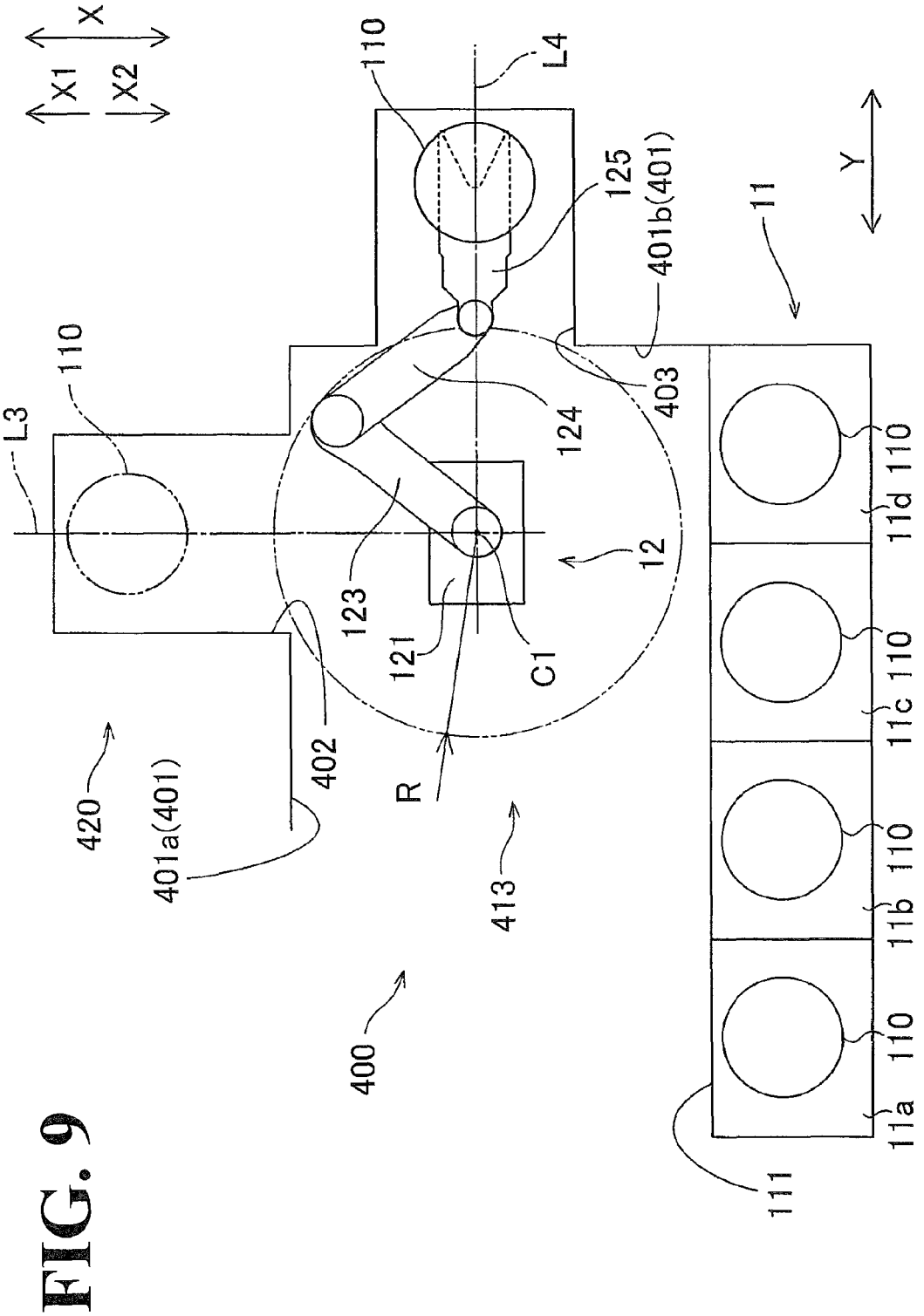
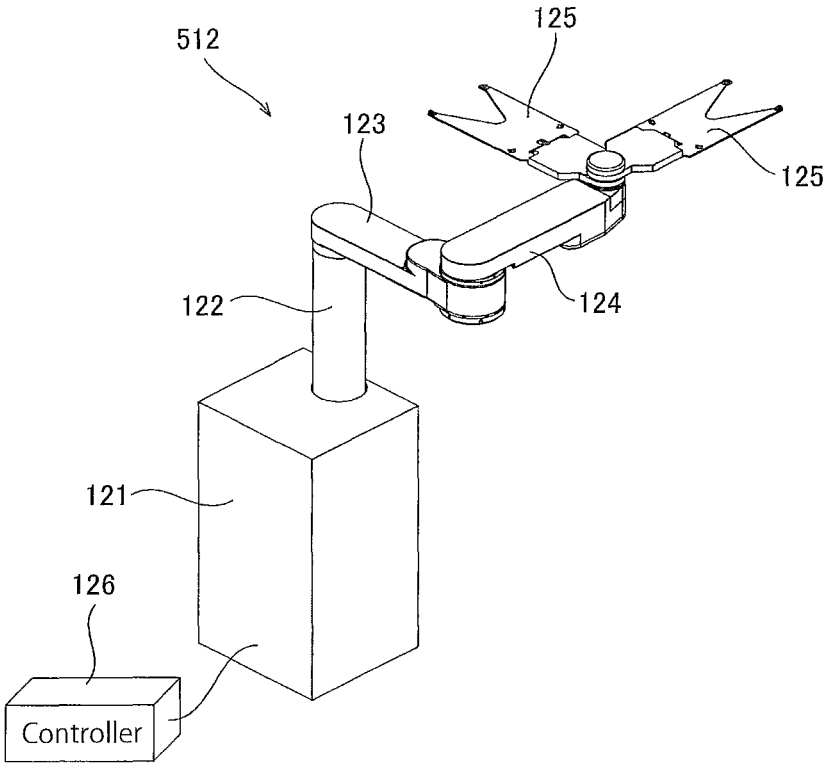

X
X1
X2
Y
110
L4
125
401b(401)
11
L3
110
124
403
123
12
121
C1
R
402
420
401a(401)
413
400
11d 110
11c 110
11b 110
11a 110
111

FIG. 9

FIG. 10



SUBSTRATE TRANSFER SYSTEM AND SUBSTRATE PROCESSING SYSTEM

CROSS-REFERENCE TO RELATED APPLICATIONS

The present application claims priority under 35 U.S.C. §119 to the U.S. Provisional Application No. 61/724,435, filed Nov. 9, 2012. The contents of this application are incorporated herein by reference in their entirety.

BACKGROUND

1. Field of the Invention

The present invention relates to a substrate transfer system and a substrate processing system.

2. Discussion of the Background

Japanese Unexamined Patent Application Publication No. 2009-136981 discloses a substrate transfer system including a substrate transfer robot that transfers a substrate to a different position.

The substrate transfer system disclosed in Japanese Unexamined Patent Application Publication No. 2009-136981 includes a robot (substrate transfer robot) that includes a lower arm, an upper arm, and a hand. The lower arm is rotatable on a horizontal surface relative to a base. The upper arm is rotatable on the horizontal surface relative to the lower arm. The hand is rotatable on the horizontal surface relative to the upper arm. The robot of the substrate transfer system is disposed in a robot installment area defined between a cassette apparatus (first apparatus) and a processing apparatus (second apparatus). The cassette apparatus accommodates substrates, and the processing apparatus processes a substrate.

SUMMARY

According to one aspect of the present disclosure, a substrate transfer system includes a substrate transfer robot disposed in a robot installment area defined between a first apparatus and a second apparatus including an opening. The substrate transfer robot includes a hand and an arm. The hand is configured to support a substrate. The arm is configured to move the hand. The arm and the hand supporting the substrate are configured to rotate on a horizontal surface within a minimal rotation area of the substrate transfer robot such that an outer periphery of the minimal rotation area overlaps an inside of the second apparatus through the opening so as to transfer the substrate from a first position in the first apparatus to a second position in the second apparatus through the opening.

According to another aspect of the present disclosure, a substrate processing system includes a first apparatus, a second apparatus including an opening, and a substrate transfer robot. The substrate transfer robot is disposed in a robot installment area defined between the first apparatus and the second apparatus. The substrate transfer robot includes a hand and an arm. The hand is configured to support a substrate. The arm is configured to move the hand. The arm and the hand supporting the substrate are configured to rotate on a horizontal surface within a minimal rotation area of the substrate transfer robot such that an outer periphery of the minimal rotation area overlaps an inside of the second apparatus through the opening so as to transfer the substrate from a first position in the first apparatus to a second position in the second apparatus through the opening.

BRIEF DESCRIPTION OF THE DRAWINGS

A more complete appreciation of the present disclosure and many of the attendant advantages thereof will be readily obtained as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings, wherein:

FIG. **1** is a plan view of a substrate processing system according to a first embodiment, illustrating a general arrangement of the substrate processing system;

FIG. **2** is a schematic side view of the substrate processing system according to the first embodiment, illustrating a general arrangement of the substrate processing system;

FIG. **3** is a perspective view of a substrate transfer robot of the substrate processing system according to the first embodiment;

FIG. **4** is a plan view of the substrate processing system according to the first embodiment, illustrating a minimal rotation area of the substrate transfer robot;

FIG. **5** illustrates a procedure of an operation by the substrate processing system according to the first embodiment in transferring a substrate placed at a position far from the substrate transfer robot;

FIG. **6** illustrates a procedure of an operation by the substrate processing system according to the first embodiment in transferring a substrate placed at a position close to the substrate transfer robot;

FIG. **7** is a schematic side view of a substrate processing system according to a second embodiment, illustrating a general arrangement of the substrate processing system;

FIG. **8** is a schematic side view of a substrate processing system according to a third embodiment, illustrating a general arrangement of the substrate processing system;

FIG. **9** is a schematic side view of a substrate processing system according to a fourth embodiment, illustrating a general arrangement of the substrate processing system; and

FIG. **10** is a perspective view of a modification of the substrate transfer robot of the substrate processing system according to any of the first to fourth embodiments.

DESCRIPTION OF THE EMBODIMENTS

The embodiments will now be described with reference to the accompanying drawings, wherein like reference numerals designate corresponding or identical elements throughout the various drawings.

First Embodiment

First, by referring to FIGS. **1** to **6**, a configuration of a substrate processing system **100** according to the first embodiment will be described.

As shown in FIGS. **1** and **2**, the substrate processing system **100** includes a substrate transfer system **10** and a processing apparatus **20**. The substrate transfer system **10** transfers a substrate **110**. In the substrate processing system **100**, the substrate transfer system **10** transfers the substrate **110** to the processing apparatus **20**. The processing apparatus **20** processes the transferred substrate **110** in a manufacturing process of a semiconductor device.

The substrate transfer system **10** includes a substrate storage apparatus **11** and a substrate transfer robot **12**. The substrate storage apparatus **11** accommodates substrates **110**, and the substrate transfer robot **12** transfers the substrate **110** between the substrate storage apparatus **11** and the processing apparatus **20**. In plan view (when viewed from above), the outer shape of the substrate transfer system **10** is a combina-

tion (indicated by the broken line in FIG. **1**) of an installment area of the substrate storage apparatus **11** and a robot installment area **13**, which is where the substrate transfer robot **12** is disposed, as described later. The robot installment area **13** is defined between a front wall **111**, described later, of the substrate storage apparatus **11** and a rear wall **201** of the processing apparatus **20**. The substrate transfer system **10** also includes an FFU (Fan Filter Unit), not shown, to keep the air inside the robot installment area **13** clean. The substrate storage apparatus **11** is an example of the "first apparatus", and the processing apparatus **20** is an example of the "second apparatus".

The substrate storage apparatus **11** corresponds to the FOUP (Front Open Unified Pod) of the SEMI (Semiconductor Equipment and Materials International) standard. As shown in FIGS. **1** and **2**, the front wall **111** of the substrate storage apparatus **11** is disposed at the side (the X1 direction side) of the substrate transfer robot **12** and the processing apparatus **20**. The front wall **111** has a perpendicular surface. The substrate storage apparatus **11** includes four cassettes **11***a* to **11***d* disposed at different positions in plan view. The four cassettes **11***a* to **11***d* are aligned next to each other in the Y direction. As shown in FIG. **2**, the four cassettes **11***a* to **11***d* are disposed on a cassette support **112**. Also the four cassettes **11***a* to **11***d* are each capable of accommodating a plurality of substrates **110** at different height positions. Specifically, each of the four cassettes **11***a* to **11***d* has 25 levels of positions in the vertical direction, accommodating a stack of up to 25 substrates **110**. The front wall **111** is an example of the "first wall", and each of the positions in the four cassettes **11***a* to **11***d* is an example of the "first position".

As shown in FIGS. **1** to **3**, the substrate transfer robot **12** is a multi-articular robot. Specifically, the substrate transfer robot **12** includes a base **121**, a support shaft **122**, a first arm **123**, a second arm **124**, a hand **125**, and a controller **126**. The controller **126** controls these elements of the substrate transfer robot **12**. The first arm **123** and the second arm **124** are examples of the "arm".

The support shaft **122** is supported by the base **121** and is elongate in the direction perpendicular to the upper surface of the base **121**. At an upper end, the support shaft **122** is coupled to one end of the first arm **123**. The first arm **123** is rotatable on a horizontal surface about the support shaft **122** as the center of rotation. At another end, the first arm **123** is coupled to one end of the second arm **124**. The second arm **124** is rotatable on the horizontal surface about, as the center of rotation, the one end of the second arm **124** coupled to the first arm **123**. At another end, the second arm **124** is coupled to the hand **125**. The hand **125** is rotatable on the horizontal surface about, as the center of rotation, the portion of the hand **125** coupled to the second arm **124**. Also the hand **125** is capable of supporting the substrate **110** from below the substrate **110**. The first arm **123** and the second arm **124** have link lengths approximately equal to one another. Specifically, as shown in FIG. **1**, the first arm **123** has a link length R1 from a center C1 of rotation of the first arm **123** to a center C2 of rotation of the second arm **124**, while the second arm **124** has a link length R2 from the center C2 of rotation of the second arm **124** to a center C3 of rotation of the hand **125**. The link length R1 and the link length R2 are approximately equal to one another. This eliminates or minimizes complexity of the operation control of the elements involved in transfer of the substrate **110**, as compared with the case where the link lengths of the first arm **123** and the second arm **124** are different from one another.

The substrate transfer robot **12** moves the support shaft **122** up and down to integrally move the first arm **123**, the second arm **124**, and the hand **125** up and down. This enables the substrate transfer robot **12** to feed and take the substrate **110** to and from all the different height positions in the cassettes **11***a* to **11***d*.

The controller **126** is taught in advance operations of the elements for transfer of the substrate **110** on the hand **125**. Specifically, the controller **126** is taught in advance operations of the elements associated with the feeding and taking operations of the substrate **110** to and from the four cassettes **11***a* to **11***d*. This ensures that the substrate transfer robot **12** performs a transfer operation with respect to the substrate **110** according to an operation procedure, described later.

As shown in FIGS. **1** and **2**, the rear wall **201** of the processing apparatus **20** is disposed at the side (the X2 direction side) of the substrate transfer robot **12** and the substrate storage apparatus **11**. The rear wall **201** has a perpendicular surface, and is approximately parallel to and opposed to the front wall **111**. On the rear wall **201**, an approximately rectangular opening **202** is disposed. As shown in FIG. **1**, the opening **202** has an opening width B in the horizontal direction (Y direction). The opening width B is large enough to allow the substrate **110** to be inserted through the opening **202**. As shown in FIG. **2**, the opening **202** has an opening length H1. The opening length H1 is larger in the height direction (Z direction) than the movable range in the height direction of the first arm **123**, the second arm **124**, and the hand **125** of the substrate transfer robot **12**. Specifically, the opening **202** is open from a first height position through to a second height position. The first height position corresponds to a position at which the substrate transfer robot **12** has access to a lowest position among the 25 levels of positions in the cassettes **11***a* to **11***d*. The second height position corresponds to another position at which the substrate transfer robot **12** has access to a highest position among the 25 levels of positions in the cassettes **11***a* to **11***d*. The rear wall **201** is an example of the "second wall".

Here, in the first embodiment, the substrate transfer robot **12** is capable of transferring a substrate **110** in the substrate storage apparatus **11** to the placement position in the processing apparatus **20** through the opening **202**, while at the same time being capable of transferring a substrate **110** in the processing apparatus **20** to a predetermined position in the substrate storage apparatus **11**. The substrate transfer robot **12** has a minimal rotation area having an outer periphery that overlaps the inside of the processing apparatus **20** through the opening **202**. Specifically, the substrate transfer robot **12** has a minimal rotation radius R, and the minimal rotation radius R is larger than the distance between the center C1 of rotation of the first arm **123** and the rear wall **201** of the processing apparatus **20**. As shown in FIG. **4**, the minimal rotation area of the substrate transfer robot **12** is an area necessary when the substrate transfer robot **12** takes a normal posture in which the first arm **123**, the second arm **124**, and the hand **125** supporting the substrate **110** are superimposed over each other and when the substrate transfer robot **12** in the normal posture rotates the first arm **123** on the horizontal surface. The placement position in the processing apparatus **20** is an example of the "second position".

When the substrate transfer robot **12** is in the normal posture, a first distance between the center C1 of rotation of the first arm **123** and the distal end of the first arm **123**, a second distance between the center C1 of rotation of the first arm **123** and the distal end of the second arm **124**, and a third distance between the center C1 of rotation of the first arm **123** and the distal end of the substrate **110** supported by the hand **125** are approximately equal to each other. Each of the first to third distances is equal to the minimal rotation radius R of the

substrate transfer robot **12** and larger than the distance between the center C1 of rotation of the first arm **123** and the rear wall **201**.

As shown in FIG. **4**, in the substrate transfer robot **12**, the center C1 of rotation of the first arm **123** is disposed at a position that faces the opening **202**. Specifically, in plan view, the center C1 of rotation of the first arm **123** is disposed on a line L1 extending from the center of the substrate **110** placed at the placement position in the processing apparatus **20** to an approximate center of the opening **202**. Also the center C1 of rotation of the first arm **123** is disposed at a position that faces the front wall **111** of the substrate storage apparatus **11**. Specifically, in plan view, the center C1 of rotation of the first arm **123** is disposed at a position that faces an approximate center in the Y direction of the four cassettes **11***a* to **11***d* of the substrate storage apparatus **11**. Also the center C1 of rotation of the first arm **123** is closer to the front wall **111** of the substrate storage apparatus **11** than to the rear wall **201** of the processing apparatus **20**. Between the substrate transfer robot **12** and the substrate storage apparatus **11**, a predetermined regulation width is included. The predetermined regulation width is determined depending on an opener (opening and closing mechanism), not shown, that opens and closes the doors of the cassettes **11***a* to **11***d*. A distance D (see FIG. **1**) between the substrate storage apparatus **11** and the processing apparatus **20** is larger than a combination of the regulation width of the opener and the distance between the base end of the hand **125** and the distal end of the substrate **110** supported by the hand **125**.

Next, an operation procedure of substrate transfer by the substrate transfer system **10** according to the first embodiment will be described.

First, by referring to FIG. **5**, description will be made with regard to an operation of transferring a substrate **110** in the cassette **11***a*, which is farther from the substrate transfer robot **12**, to the placement position in the processing apparatus **20**. As shown in the lower right-hand corner of FIG. **5**, the substrate transfer robot **12** moves the hand **125** to a position under a substrate **110** in the cassette **11***a* so as to support the substrate **110**. Then, the substrate transfer robot **12** linearly moves the hand **125** toward the processing apparatus **20** (in the X1 direction), thereby pulling the substrate **110** out of the cassette **11***a*, and takes a stand-by posture. Then, the substrate transfer robot **12** rotates the hand **125** alone to put a center **110***a* of the substrate **110** onto an imaginary line L2, thus taking a first intermediate posture. The imaginary line L2 extends in a direction (Y direction) approximately parallel to the rear wall **201** of the processing apparatus **20** in plan view, and is at an approximately equal distance from the front wall **111** and the rear wall **201**. In the first intermediate posture, the substrate transfer robot **12** does not protrude into the processing apparatus **20**.

The substrate transfer robot **12** changes from the first intermediate posture into a second intermediate posture. Specifically, the substrate transfer robot **12** transfers the substrate **110** with the center **110***a* of the substrate **110** moving along the imaginary line L2, thereby folding the first arm **123** and the second arm **124** together and changing into the second intermediate posture. Here, by folding the first arm **123** and the second arm **124** together, the substrate transfer robot **12** makes the ends of the first arm **123** and the second arm **124** protrude into the processing apparatus **20** through the opening **202**.

Then, the substrate transfer robot **12** rotates the hand **125** so as to fold the first arm **123**, the second arm **124**, and the hand **125** together, thereby changing from the second intermediate posture into the normal posture. Here, the first arm **123**, the second arm **124**, and the hand **125** are disposed with their lengths oriented in a direction (X direction) orthogonal to the rear wall **201**. Also the ends of the first arm **123** and the second arm **124** and a part of the substrate **110** supported by the hand **125** protrude into the processing apparatus **20** through the opening **202**.

Then, the substrate transfer robot **12** changes from the normal posture into a third intermediate posture. Specifically, the substrate transfer robot **12** rotates the first arm **123** and the second arm **124** with the first arm **123** and the second arm **124** folded together, thereby making the first arm **123** and the second arm **124** extend in the Y1 direction from the center C1 of rotation of the first arm **123** side and changing into the third intermediate posture. That is, the first arm **123** and the second arm **124** are oriented in one direction (the Y1 direction) among the directions (Y directions) that are orthogonal to the direction (X direction) that is from the center C1 of rotation of the first arm **123** to the placement position in the processing apparatus **20**. Also in the third intermediate posture, the substrate **110** supported by the hand **125** is partially beyond the opening **202**. Then, the substrate transfer robot **12** changes from the third intermediate posture by linearly moving the hand **125** in the direction (X1 direction) of the placement position in the processing apparatus **20**, thereby transferring the substrate **110** to the placement position in the processing apparatus **20**.

These movements ensure transfer of the substrate **110** from the cassette **11***a* to the placement position in the processing apparatus **20** without the substrate transfer robot **12** contacting the substrate storage apparatus **11** and the processing apparatus **20**. When transferring the substrate **110** from the placement position in the processing apparatus **20** to the cassette **11***a*, the substrate transfer robot **12** may follow the above-described operation procedure in reverse order, so as to ensure transfer without the substrate transfer robot **12** contacting the substrate storage apparatus **11** and the processing apparatus **20**. When transferring to the placement position in the processing apparatus **20** the substrate **110** in the cassette **11***d*, which is at the opposite side of the cassette **11***a* in the Y directions relative to the center the substrate storage apparatus **11**, the substrate transfer robot **12** may follow the above-described operation procedure similarly to the cassette **11***a*, so as to ensure transfer. In the first embodiment, in the third intermediate posture of the substrate transfer robot **12**, the first arm **123** and the second arm **124** extend in the Y1 direction from the center C1 of rotation of the first arm **123** in both cases of the cassettes **11***a* and **11***d*.

Next, by referring to FIG. **6**, description will be made with regard to an operation of transferring a substrate **110** in the cassette **11***b*, which is closer to the substrate transfer robot **12**, to the placement position in the processing apparatus **20**. As shown in the lower right-hand corner of FIG. **6**, the substrate transfer robot **12** moves the hand **125** to a position under a substrate **110** in the cassette **11***b* so as to support the substrate **110**. Then, the substrate transfer robot **12** linearly moves the hand **125** toward the processing apparatus **20** (in the X1 direction), thereby pulling the substrate **110** out of the cassette **11***b*, and takes the stand-by posture. In this state of the substrate transfer robot **12**, the ends of the first arm **123** and the second arm **124** protrude into the processing apparatus **20** through the opening **202**. Then, the substrate transfer robot **12** rotates the hand **125** alone to put the center **110***a* of the substrate **110** onto the imaginary line L2, thus taking the first intermediate posture.

The substrate transfer robot **12** changes from the first intermediate posture into the second intermediate posture. Specifically, the substrate transfer robot **12** transfers the substrate

110 with the center 110*a* of the substrate 110 moving along the imaginary line L2, thereby folding the first arm 123 and the second arm 124 together and changing into the second intermediate posture. Here, by folding the first arm 123 and the second arm 124 together, the substrate transfer robot 12 makes the ends of the first arm 123 and the second arm 124 protrude into the processing apparatus 20 through the opening 202. That is, throughout the stand-by posture, the first intermediate posture, and the second intermediate posture of the substrate transfer robot 12, the ends of the first arm 123 and the second arm 124 protrude into the processing apparatus 20.

Then, the substrate transfer robot 12 rotates the hand 125 so as to fold the first arm 123, the second arm 124, and the hand 125 together, thereby changing from the second intermediate posture into the normal posture. Here, the first arm 123, the second arm 124, and the hand 125 are disposed with their lengths oriented in the direction (X direction) orthogonal to the rear wall 201. Also the ends of the first arm 123 and the second arm 124 and a part of the substrate 110 supported by the hand 125 protrude into the processing apparatus 20 through the opening 202.

Then, similarly to the case of the cassette 11*a*, the substrate transfer robot 12 takes the third intermediate posture, in which the first arm 123 and the second arm 124 extend in the Y1 direction from the center C1 of rotation of the first arm 123. Then, the substrate transfer robot 12 changes from the third intermediate posture by linearly moving the hand 125 in the direction (X1 direction) of the placement position in the processing apparatus 20, thereby transferring the substrate 110 to the placement position in the processing apparatus 20.

These movements ensure transfer of the substrate 110 from the cassette 11*b* to the placement position in the processing apparatus 20 without the substrate transfer robot 12 contacting the substrate storage apparatus 11 and the processing apparatus 20. When transferring the substrate 110 from the placement position in the processing apparatus 20 to the cassette 11*b*, the substrate transfer robot 12 may follow the above-described operation procedure in reverse order, so as to ensure transfer without the substrate transfer robot 12 contacting the substrate storage apparatus 11 and the processing apparatus 20. When transferring to the placement position in the processing apparatus 20 the substrate 110 in the cassette 11*c*, which is at the opposite side of the cassette 11*b* in the Y directions relative to the center the substrate storage apparatus 11, the substrate transfer robot 12 may follow the above-described operation procedure similarly to the cassette 11*b*, so as to ensure transfer. In the first embodiment, in the third intermediate posture of the substrate transfer robot 12, the first arm 123 and the second arm 124 extend in the Y1 direction from the center C1 of rotation of the first arm 123 in both cases of the cassettes 11*b* and 11*c*. That is, in all of the cases of the cassettes 11*a* to 11*d*, in the third intermediate posture of the substrate transfer robot 12, the first arm 123 and the second arm 124 are oriented in the same direction (the Y1 direction) as viewed from the center C1 of rotation of the first arm 123.

In the first embodiment, the substrate transfer robot 12 transfers the substrate 110 from a position in the substrate storage apparatus 11 to the placement position in the processing apparatus 20 through the opening 202, which is disposed on the processing apparatus 20. Here, with the hand 125 supporting the substrate 110, the outer periphery of the minimal rotation area of the substrate transfer robot 12 overlaps the inside of the processing apparatus 20 through the opening 202. Thus, the opening 202, which is for transfer of the substrate 110 into the processing apparatus 20, is utilized in the rotation of the substrate transfer robot 12. This minimizes the distance between the substrate transfer robot 12 and the processing apparatus 20, as compared with the processing apparatus 20 being disposed to avoid overlapping with the minimal rotation area of the substrate transfer robot 12. This, as a result, diminishes the robot installment area 13 and ensures miniaturization. The diminished robot installment area 13 also ensures a diminished FFU (fan filter unit). This is particularly effective in applications where the robot installment area 13 needs to be kept clean by the FFU, as in the first embodiment. The miniaturization is effective in applications where the substrate processing system 100 accommodates a plurality of apparatuses and is liable to increase in size, as in the first embodiment.

Also in the first embodiment, in the substrate transfer robot 12, the center C1 of rotation of the first arm 123 is at a position that faces the opening 202 in plan view, and the minimal rotation radius R of the substrate transfer robot 12 is larger than the distance between the center C1 of rotation of the first arm 123 and the processing apparatus 20. This configuration ensures that the outer periphery of the minimal rotation area of the substrate transfer robot 12 easily overlaps the inside of the processing apparatus 20 through the opening 202. This, in turn, easily diminishes the robot installment area 13 and ensures miniaturization.

Also in the first embodiment, in the substrate transfer robot 12, the center C1 of rotation of the first arm 123 is closer to the front wall 111 than to the rear wall 201 in plan view, and the minimal rotation radius R of the substrate transfer robot 12 is larger than the distance between the center C1 of rotation of the first arm 123 and the rear wall 201. This configuration reduces the distance between the substrate transfer robot 12 and the front wall 111 as well as reducing the distance between the substrate transfer robot 12 and the rear wall 201. This, in turn, further diminishes the robot installment area 13 and results in further miniaturization.

Also in the first embodiment, the substrate transfer robot 12 takes the normal posture in which the first arm 123, the second arm 124, and the hand 125 supporting the substrate 110 are superimposed over each other in plan view. The substrate transfer robot 12 in the normal posture rotates within the minimal rotation area when the first arm 123 rotates on the horizontal surface about the one end of the first arm 123 as the center C1 of rotation. This configuration eliminates or minimizes enlargement of the minimal rotation area even when the substrate transfer robot 12 is provided with two arms (the first arm 123 and the second arm 124) and the hand 125. This, in turn, eliminates or minimizes enlargement of the robot installment area 13.

Also in the first embodiment, in the normal posture of the substrate transfer robot 12, the first distance between the center C1 of rotation of the first arm 123 and the distal end of the first arm 123, the second distance between the center C1 of rotation of the first arm 123 and the distal end of the second arm 124, and the third distance between the center C1 of rotation of the first arm 123 and the distal end of the substrate 110 supported by the hand 125 are approximately equal to each other. This configuration increases the maximum length of the first arm 123, the second arm 124, and the hand 125 in unfolded state while eliminating or minimizing enlargement of the minimal rotation area of the substrate transfer robot 12. This, in turn, ensures a wide transferable range of the substrate 110 while eliminating or minimizing enlargement of the robot installment area 13.

Also in the first embodiment, when the substrate transfer robot 12 transfers the substrate 110 from a position in the substrate storage apparatus 11 to the placement position in the

processing apparatus **20**, the substrate transfer robot **12** folds the first arm **123** and the second arm **124** together and protrudes the arm (the first arm **123** and the second arm **124**) into the processing apparatus **20** through the opening **202**. This configuration facilitates the folding of the first arm **123** and the second arm **124** without the arm of the substrate transfer robot **12** contacting the processing apparatus **20** even though the folding involves overlapping of the arm with the area of the processing apparatus.

Also in the first embodiment, the substrate transfer robot **12** moves the substrate **110** while keeping the center of the substrate **110** along the imaginary line L2, which is approximately parallel to the rear wall **201** of the processing apparatus **20** in plan view, so as to fold the first arm **123** and the second arm **124** together and protrude the arm (the first arm **123** and the second arm **124**) into the processing apparatus **20** through the opening **202**. This configuration ensures that the substrate **110** is moved with a uniform distance secured from the processing apparatus **20**. This, in turn, facilitates the folding of the first arm **123** and the second arm **124** without the substrate **110** contacting the processing apparatus **20**.

Also in the first embodiment, the substrate transfer robot **12** rotates the hand **125** supporting the substrate **110** relative to the second arm **124** so as to take the first intermediate posture, in which the center of the substrate **110** is on the imaginary line L2. The substrate transfer robot **12** moves from the first intermediate posture while keeping the center of the substrate **110** along the imaginary line L2 so as to change into the second intermediate posture, in which the first arm **123** and the second arm **124** are folded together. The substrate transfer robot **12** moves from the second intermediate posture so as to transfer the substrate **110** to the placement position in the processing apparatus **20**. This configuration easily keeps the center of the substrate **110** on the imaginary line L2 merely by rotating the hand **125**, and facilitates the folding of the first arm **123** and the second arm **124** by moving the center of the substrate **110** along the imaginary line L2.

Also in the first embodiment, the imaginary line L2 is at an approximately equal distance from the front wall **111** and the rear wall **201**. This configuration ensures that the substrate **110** is moved with a uniform distance secured both from the front wall **111** and the rear wall **201**. This, in turn, facilitates the folding of the first arm **123** and the second arm **124** without the substrate **110** contacting the front wall **111** and the rear wall **201**.

Also in the first embodiment, when the substrate transfer robot **12** transfers any one substrate **110** in the cassettes **11***a* to **11***d* to the placement position in the processing apparatus **20**, the substrate transfer robot **12** takes the third intermediate posture, in which with the substrate **110** partially beyond the opening **202**, the first arm **123** and the second arm **124** are folded together and oriented in one direction (the Y1 direction) that is approximately orthogonal to the direction (X direction) that is from the center C1 of rotation of the first arm **123** to the placement position in the processing apparatus **20**. This configuration ensures that the first arm **123** and the second arm **124** are oriented in the same direction no matter which substrate **110** is transferred. This, in turn, eliminates or minimizes variations of accuracy of substrate transfer caused by a backlash that can occur when, for example, a gear is used to rotate the first arm **123** and the second arm **124**.

Also in the first embodiment, the opening **202** is open from a first height position through to a second height position. The first height position corresponds to a position at which the hand **125** and the arm (the first arm **123** and the second arm **124**) have access to a substrate **110** placed at a lowest position in the cassettes **11***a* to **11***d* of the substrate storage apparatus **11**. The second height position corresponds to another position at which the hand **125** and the arm have access to a substrate **110** placed at a highest position in the cassettes **11***a* to **11***d* of the substrate storage apparatus **11**. This configuration ensures that the substrate transfer robot **12** easily rotates itself by utilizing the opening **202**, no matter which height position in the cassettes **11***a* to **11***d* the substrate **110** to be transferred by the substrate transfer robot **12** is placed at. This, in turn, ensures that even when the substrates **110** are stacked in the cassettes **11***a* to **11***d*, the substrate transfer robot **12** easily transfers the substrate **110** without contacting the processing apparatus **20**, while at the same time ensuring a reduction in size of the substrate processing system **100**.

Second Embodiment

Next, a second embodiment will be described by referring to FIG. **7**. The second embodiment is different from the first embodiment in that an opening **202***a* according to the second embodiment has an opening length, H2, that is smaller in height (in the Z direction) than the opening length H1 of the opening **202** according to the first embodiment. The same reference numerals designate identical or corresponding elements throughout the first and second embodiments, and these elements will not be elaborated here.

As shown in FIG. **7**, a substrate processing system **200** according to the second embodiment includes a processing apparatus **220**. The opening **202***a* of the processing apparatus **220** has the opening length **112**. The opening length H2 is smaller than the movable range in the height direction of the first arm **123**, the second arm **124**, and the hand **125** of the substrate transfer robot **12**. Specifically, the opening **202***a* is open through to a height corresponding to a height position at which the substrate transfer robot **12** has access to the lowest position among the 25 levels of positions in the cassettes **11***b* and **11***c*, which are closer to the substrate transfer robot **12**. The processing apparatus **220** is an example of the "second apparatus".

Also in the second embodiment, the substrate transfer robot **12** is capable of feeding and taking the substrate **110** to and from all the 25 levels of positions in the cassettes **11***a* and **11***d*, which are farther from the substrate transfer robot **12** among the four cassettes **11***a* to **11***d* of the substrate storage apparatus **11**. For the cassettes **11***b* and **11***c*, which are closer to the substrate transfer robot **12** among the four cassettes **11***a* to **11***d* of the substrate storage apparatus **11**, the substrate transfer robot **12** is capable of feeding and taking the substrate **110** to and from a lowest position among the 25 levels of positions. The position in each of the cassettes **11***b* and **11***c* is an example of the "first position", and the position in each of the cassettes **11***a* and **11***d* is an example of the "third position".

Next, an operation procedure of substrate transfer by the substrate transfer system **10** according to the second embodiment will be described.

First, by referring to FIG. **5**, description will be made with regard to an operation of transferring a substrate **110** in the cassette **11***a*, which is farther from the substrate transfer robot **12**, to the placement position in the processing apparatus **220**. Similarly to the first embodiment, the substrate transfer robot **12** moves the hand **125** to a position under a substrate **110** in the cassette **11***a* so as to support the substrate **110**. Then, the substrate transfer robot **12** linearly moves the hand **125** toward the processing apparatus **220** (in the X1 direction), thereby pulling the substrate **110** out of the cassette **11***a*, and takes the stand-by posture. Here, the substrate transfer robot **12** does not protrude into the processing apparatus **220**.

Here, in the second embodiment, the substrate transfer robot **12** in the stand-by posture moves the support shaft **122** up and down to move the first arm **123**, the second arm **124**, and the hand **125** to a height position corresponding to the opening **202***a*. This ensures that the substrate transfer robot **12** is able to, in its later movements, protrude the first arm **123**, the second arm **124**, and the hand **125** into the processing apparatus **220** through the opening **202***a*. The movements following the stand-by posture are similar to the movements in the first embodiment and will not be elaborated here.

The movements of the substrate transfer robot **12** according to the second embodiment involved in the transfer of a substrate **110** placed at a lowest position in the cassettes **11***b* and **11***c*, which are closer to the substrate transfer robot **12**, to the placement position in the processing apparatus **220** are similar to the movements in the first embodiment and will not be elaborated here. In the substrate transfer robot **12** according to the second embodiment, it is not possible to transfer substrates **110** other than the substrate **110** at the lowest position in the cassettes **11***b* and **11***c*, which are closer to the substrate transfer robot **12**; otherwise, the substrate transfer robot **12** would come into contact with the processing apparatus **220**.

The second embodiment is otherwise similar to the first embodiment.

In the second embodiment, the opening **202***a* is open through to a height corresponding to a substrate **110** placed at the cassettes **11***b* and **11***c*, which are closer to the substrate transfer robot **12**. When the substrate transfer robot **12** seeks access to a position in the cassettes **11***a* and **11***d*, which are farther from the substrate transfer robot **12**, the substrate transfer robot **12** pulls the substrate **110** out of the cassette **11***a* or **11***d*, and then moves the hand **125** and the arm (the first arm **123** and the second arm **124**) in the height direction so as to protrude the arm into the processing apparatus **220** through the opening **202***a*. This configuration diminishes the robot installment area **13** and ensures miniaturization while inhibiting an excessive increase in size of the opening **202***a*. Inhibiting an excessive increase in size of the opening **202***a* eliminates or minimizes contamination of the robot installment area **13**, in which the air needs to be kept clean, by foreign matter through the opening **202***a*.

The advantageous effects of the second embodiment are otherwise similar to the advantageous effects of the first embodiment.

Third Embodiment

Next, a third embodiment will be described by referring to FIG. **8**. In the third embodiment, a robot installment area **313** is defined between two processing apparatuses **20** and **320**, as opposed to the robot installment area **13** according to the first embodiment, which is defined between the substrate storage apparatus **11** and the processing apparatus **20**. The same reference numerals designate identical or corresponding elements throughout the first and third embodiments, and these elements will not be elaborated here.

As shown in FIG. **8**, in a substrate processing system **300** according to the third embodiment, the two processing apparatuses **20** and **320** are aligned in the X direction and face one another. The processing apparatus **320** has a configuration similar to the configuration of the processing apparatus **20** according to the first embodiment, and is symmetrical relative to the processing apparatus **20** about a center line between the two processing apparatuses **20** and **320**. Specifically, the processing apparatus **320** includes a front wall **301** and an opening **302**, which respectively correspond to the rear wall **201** and the opening **202** of the processing apparatus **20**. The processing apparatus **320** is an example of the "first apparatus", and the front wall **301** is an example of the "first wall".

The robot installment area **313** according to the third embodiment is defined between the rear wall **201** of the processing apparatus **20** and the front wall **301** of the processing apparatus **320**. In the robot installment area **313**, the substrate transfer robot **12** is disposed. The substrate transfer robot **12** is capable of transferring a substrate **110** between the two processing apparatuses **20** and **320**. The substrate transfer robot **12** is disposed at such a position that the outer periphery of the minimal rotation area overlaps the inside of the processing apparatus **20** through the opening **202** of the processing apparatus **20**. Also the position of the substrate transfer robot **12** is where the outer periphery of the minimal rotation area overlaps the inside of the processing apparatus **320** through the opening **302** of the processing apparatus **320**. That is, the minimal rotation radius R of the substrate transfer robot **12** is larger than the distance between the center C1 of rotation of the first arm **123** and the rear wall **201** of the processing apparatus **20**, and is larger than the distance between the center C1 of rotation of the first arm **123** and the front wall **301** of the processing apparatus **320**. The substrate transfer robot **12** is capable of 360-degree rotation when in the normal posture, in which the first arm **123**, the second arm **124**, and the hand **125** are superimposed over each other.

Also in the substrate transfer robot **12**, the center C1 of rotation of the first arm **123** is disposed at a position that faces both the openings **202** and **302**. Specifically, in plan view, the center C1 of rotation of the first arm **123** is disposed on a line L1 extending from the center of the substrate **110** placed at the placement position in the processing apparatus **20** to an approximate center of the opening **202**. Also in the third embodiment, the two processing apparatuses **20** and **320** and the substrate transfer robot **12** are disposed such that the line L1 passes through the center of the substrate **110** at the placement position in the processing apparatus **320** and through an approximate center of the opening **302** of the processing apparatus **320**. The center C1 of rotation of the first arm **123** is at an approximately equal distance from the two processing apparatuses **20** and **320**. The placement position in the processing apparatus **320** is an example of the "first position".

The third embodiment is otherwise similar to the first embodiment.

In the third embodiment, the substrate transfer robot **12** is disposed in the robot installment area **313** defined between the two opposing processing apparatuses **20** and **320**. In this configuration, the outer periphery of the minimal rotation area of the substrate transfer robot **12** overlaps the insides of the processing apparatuses **20** and **320** respectively through the openings **202** and **302**. This reduces the distance between the substrate transfer robot **12** and the one processing apparatus **20** and the distance between the substrate transfer robot **12** and the other processing apparatus **320** at the same time. This diminishes the robot installment area **313** and ensures miniaturization of the substrate processing system **300** even when the substrate transfer robot **12** is disposed in the robot installment area **313** defined between the two processing apparatuses **20** and **320**.

The advantageous effects of the third embodiment are otherwise similar to the advantageous effects of the first embodiment.

Fourth Embodiment

Next, a fourth embodiment will be described by referring to FIG. **9**. The fourth embodiment is different from the first

embodiment in that a processing apparatus **420** has two placement positions located in directions approximately orthogonal to one another from the center C1 of rotation of the first arm **123**. The same reference numerals designate identical or corresponding elements throughout the first and fourth embodiments, and these elements will not be elaborated here.

As shown in FIG. **9**, in a substrate processing system **400** according to the fourth embodiment, the processing apparatus **420** includes an approximately L-shaped wall **401**. The wall **401** includes a rear wall **401***a* and a side wall **401***b*. The rear wall **401***a* is approximately parallel to the front wall **111** of the substrate storage apparatus **11**, and the side wall **401***b* is approximately perpendicular to the front wall **111**. The rear wall **401***a* has an approximately rectangular opening **402**. The side wall **401***b* has an approximately rectangular opening **403**. The processing apparatus **420** is an example of the "second apparatus", and the rear wall **401***a* is an example of the "second wall".

In the fourth embodiment, a robot installment area **413** is defined between the front wall **111** of the substrate storage apparatus **11** and the approximately L-shaped wall **401** of the processing apparatus **420**. In the robot installment area **413**, the substrate transfer robot **12** is disposed. The substrate transfer robot **12** is capable of transferring a substrate **110** among the substrate storage apparatus **11** and two placement positions in the processing apparatus **420**. Also the substrate transfer robot **12** is disposed at such a position that the outer periphery of the minimal rotation area overlaps the inside of the processing apparatus **420** through the opening **402** of the rear wall **401***a* and the opening **403** of the side wall **401***b*. That is, the minimal rotation radius R of the substrate transfer robot **12** is larger than the distance between the center C1 of rotation of the first arm **123** and the rear wall **401***a*, and larger than the distance between the center C1 of rotation of the first arm **123** and the side wall **401***b*. The two placement positions in the processing apparatus **420** are examples of the "second position".

In the substrate transfer robot **12**, the center C1 of rotation of the first arm **123** is disposed at a position that faces both the openings **402** and **403**. Specifically, in plan view, the center C1 of rotation of the first arm **123** is disposed on a line L3 extending from the center of a substrate **110** placed at one placement position in the processing apparatus **420** to an approximate center of the opening **402** of the rear wall **401***a*. Also in plan view, the center C1 of rotation of the first arm **123** is disposed on a line L4 extending from the center of a substrate **110** placed at the other placement position in the processing apparatus **420** to an approximate center of the opening **403** of the side wall **401***b*. The line L3 and the line L4 are approximately orthogonal to one another. The substrate transfer robot **12** is disposed such that the distance between the center C1 of rotation of the first arm **123** and the front wall **111** of the substrate storage apparatus **11** is larger than the minimal rotation radius R. The substrate transfer robot **12** is capable of 360-degree rotation when in the normal posture, in which the first arm **123**, the second arm **124**, and the hand **125** are superimposed over each other.

The fourth embodiment is otherwise similar to the first embodiment.

In the fourth embodiment, the processing apparatus **420** has two placement positions located in directions approximately orthogonal to one another from the center C1 of rotation of the first arm **123**. In this configuration, the outer periphery of the minimal rotation area of the substrate transfer robot **12** overlaps the inside of the processing apparatus **420** through the opening **402** of the rear wall **401***a* and the opening **403** of the side wall **401***b*. This reduces both the distance between the substrate transfer robot **12** and the rear wall **401***a* and the distance between the substrate transfer robot **12** and the side wall **401***b*. This, in turn, diminishes the robot installment area **413** in two orthogonal directions (X direction and Y direction), the robot installment area **413** being defined by the front wall **111** of the substrate storage apparatus **11**, the rear wall **401***a*, and the side wall **401***b*, which is approximately orthogonal to the rear wall **401***a*.

The advantageous effects of the fourth embodiment are otherwise similar to the advantageous effects of the first embodiment.

In the first to fourth embodiments, the substrate transfer robot has been exemplified as including two arms (the first arm and the second arm). This, however, should not be construed in a limiting sense. The substrate transfer robot may include a single arm or three or more arms.

Also in the first to fourth embodiments, the substrate transfer robot has been exemplified as including a single hand. This, however, should not be construed in a limiting sense. As shown in FIG. **10**, a substrate transfer robot **512** including two hands is also possible. A substrate transfer robot including three or more hands is also possible.

In the first embodiment, the imaginary line has been exemplified as being at an approximately equal distance from the first wall and the second wall. This, however, should not be construed in a limiting sense. The imaginary line may be closer to either the first wall or the second wall insofar as no interference occurs between the substrate transfer robot and the first and second walls when the substrate transfer robot changes from the first intermediate posture to the second intermediate posture.

Also in the first to fourth embodiments, the robot installment area has been exemplified as being defined between the front wall (first wall) and the rear wall (second wall) that are approximately parallel to one another. This, however, should not be construed in a limiting sense. The robot installment area may be defined between a first wall and a second wall that are orthogonal to one another.

Also in the first to fourth embodiments, the second apparatus has been exemplified as a processing apparatus in a manufacturing process of a semiconductor device. This, however, should not be construed in a limiting sense. The second apparatus may be other than the processing apparatus in a manufacturing process of a semiconductor device. Other examples include a temporary substrate stand apparatus to forward a substrate to a next step.

Also in the first to fourth embodiments, the center of rotation of the first arm has been exemplified as being on a line extending from the center of the substrate placed at the placement position in the processing apparatus (second apparatus) to an approximate center of the opening. This, however, should not be construed in a limiting sense. The center of rotation of the first arm may be off the line extending from the center of the substrate placed at the placement position in the second apparatus to an approximate center of the opening, insofar as the center of rotation of the first arm is disposed at a position that faces the opening.

Also in the first to fourth embodiments, the first distance between the center of rotation of the first arm and the distal end of the first arm, the second distance between the center of rotation of the first arm and the distal end of the second arm, and the third distance between the center of rotation of the first arm and the distal end of the substrate supported by the hand are approximately equal to each other, and the first to third distances are larger than the distance between the center of rotation of the first arm and the rear wall (second wall). This, however, should not be construed in a limiting sense. At

least one distance among the first to third distances may be larger than the distance between the center of rotation of the first arm and the second wall.

Also in the first to fourth embodiments, the opening has been exemplified as being provided on the rear wall (second wall) of the processing apparatus serving as the second apparatus. This, however, should not be construed in a limiting sense. For example, it is possible to provide the first apparatus with both a first wall and a second wall provided with an opening. It is also possible to provide a second wall separate from the first apparatus and the second apparatus, and provide an opening on the second wall.

In the first and second embodiments, when the substrate is transferred from any of the cassettes, the first arm and the second arm have been exemplified as being oriented in one direction (in the Y1 direction) from the center of rotation of the first arm in the third intermediate posture. This, however, should not be construed in a limiting sense. To minimize the time spent in transferring the substrate, it is possible in the third intermediate posture to change the orientation of the first arm and the second arm conveniently depending on the position of the cassette.

In the second embodiment, the cassettes **11***b* and **11***c*, which are closer to the substrate transfer robot, have been exemplified as accommodating substrates only at the lowest positions in the cassettes **11***b* and **11***c*, with the opening length H2 of the opening being set at a height corresponding to a position at which the substrate transfer robot has access to the lowest positions in the cassettes **11***b* and **11***c*, which are closer to the substrate transfer robot. This, however, should not be construed in a limiting sense. It is possible to accommodate and stack a plurality of substrates in the cassettes **11***b* and **11***c*, which are closer to the substrate transfer robot, insofar as the opening has a height corresponding to the position at which the substrate transfer robot has access to any of the substrates accommodated in the cassettes **11***b* and **11***c*, which are closer to the substrate transfer robot.

Obviously, numerous modifications and variations of the present disclosure are possible in light of the above teachings. It is therefore to be understood that within the scope of the appended claims, the present disclosure may be practiced otherwise than as specifically described herein.

What is claimed as new and desired to be secured by Letters Patent of the United States is:

1. A substrate transfer system comprising:

a substrate transfer robot disposed in a robot installment area defined between a first apparatus and a second apparatus comprising an opening, the robot installment area including a plurality of side walls, the first apparatus including a plurality of cassettes disposed at different locations in the first apparatus and each configured to accommodate at least one substrate, the substrate transfer robot being configured to transfer the at least one substrate from each of the plurality of cassettes to the second apparatus via the opening, the substrate transfer robot comprising:

a base stationary relative to the robot installment area;

a hand configured to support the at least one substrate; and

an arm rotatably mounted to the base about a center of rotation to move the hand, the arm and the hand supporting the at least one substrate being configured to rotate on a horizontal surface within a minimal rotation area of the substrate transfer robot such that an outer periphery of the minimal rotation area overlaps an inside of the second apparatus through the opening so as to transfer the at least one substrate from a first position in any one of the plurality of cassettes disposed in the first apparatus to a second position in the second apparatus through the opening,

wherein the minimal rotation area is defined by a minimal rotation radius that is an outermost radius of the substrate transfer robot from the center of rotation when the substrate transfer robot is in a collapsed state,

wherein the minimal rotation radius is larger than a first minimum distance between the center of rotation and a first side wall of the plurality of side walls, and

wherein the minimal rotation radius is larger than a second minimum distance between the center of rotation and a second side wall of the plurality of side walls.

2. The substrate transfer system according to claim **1**,

wherein the arm comprises a first arm configured to rotate on the horizontal surface about one end of the first arm as the center of rotation, and

wherein the center of rotation of the first arm is at a position that faces the opening in plan view, and the substrate transfer robot comprises a minimal rotation radius larger than a distance between the center of rotation of the first arm and the second apparatus.

3. The substrate transfer system according to claim **2**,

wherein the robot installment area is defined between a first wall and a second wall, the first wall being disposed at the first apparatus, the second wall being disposed at the second apparatus and approximately parallel to the first wall, and

wherein the center of rotation of the first arm is closer to the first wall than to the second wall in plan view, and the substrate transfer robot comprises a minimal rotation radius larger than a distance between the center of rotation of the first arm and the second wall.

4. The substrate transfer system according to claim **2**,

wherein the arm comprises a second arm comprising one end coupled to another end of the first arm, the second arm being configured to rotate on the horizontal surface relative to the first arm,

wherein the hand is coupled to another end of the second arm and configured to rotate on the horizontal surface relative to the second arm,

wherein the substrate transfer robot is configured to take a normal posture in which the first arm, the second arm, and the hand supporting the at least one substrate are superimposed over each other in plan view, and is configured to rotate within the minimal rotation area when the first arm rotates on the horizontal surface about the one end of the first arm as the center of rotation, and

wherein with the substrate transfer robot taking the normal posture, at least one distance among a first distance between the center of rotation of the first arm and a distal end of the first arm, a second distance between the center of rotation of the first arm and a distal end of the second arm, and a third distance between the center of rotation of the first arm and a distal end of the at least one substrate supported by the hand is larger than the distance between the center of rotation of the first arm and the second apparatus in plan view.

5. The substrate transfer system according to claim **4**, wherein the first distance, the second distance, and the third distance are approximately equal to each other, and each of the first distance, the second distance, and the third distance is larger than the distance between the center of rotation of the first arm and the second apparatus.

6. The substrate transfer system according to claim **4**, wherein when the substrate transfer robot transfers the at least one substrate from the first position in the first apparatus to the

second position in the second apparatus, the substrate transfer robot is configured to fold the first arm and the second arm together and protrude the arm into the second apparatus through the opening.

7. The substrate transfer system according to claim **6**, wherein the substrate transfer robot is configured to transfer the at least one substrate while keeping a center of the at least one substrate along an imaginary line that is approximately parallel to the second apparatus in plan view, so as to fold the first arm and the second arm together and protrude the arm into the second apparatus through the opening.

8. The substrate transfer system according to claim **7**,

wherein the substrate transfer robot is configured to rotate the hand supporting the at least one substrate relative to the second arm from a state in which the hand supports the at least one substrate at the first position in the first apparatus so as to take a first intermediate posture in which the center of the at least one substrate is on the imaginary line,

wherein the substrate transfer robot is configured to move from the first intermediate posture while keeping the center of the at least one substrate along the imaginary line so as to change into a second intermediate posture in which the first arm and the second arm are folded together, and

wherein the substrate transfer robot is configured to move from the second intermediate posture so as to transfer the at least one substrate to the second position in the second apparatus.

9. The substrate transfer system according to claim **7**,

wherein the robot installment area is defined between a first wall and a second wall, the first wall being disposed at the first apparatus, the second wall being disposed at the second apparatus and approximately parallel to the first wall, and

wherein the imaginary line is at approximately a same distance from the first wall and the second wall.

10. The substrate transfer system according to claim **4**,

wherein the first apparatus is configured to accommodate a plurality of substrates at different positions in plan view, and

wherein the substrate transfer robot is configured to transfer any one substrate among the plurality of substrates in the first apparatus to the second position in the second apparatus such that with the one substrate partially beyond the opening, the first arm and the second arm are folded together and oriented in one direction that is approximately orthogonal to a direction that is from the center of rotation of the first arm to the second position in the second apparatus.

11. The substrate transfer system according to claim **5**, wherein when the substrate transfer robot transfers the at least one substrate from the first position in the first apparatus to the second position in the second apparatus, the substrate transfer robot is configured to fold the first arm and the second arm together and protrude the arm into the second apparatus through the opening.

12. The substrate transfer system according to claim **3**,

wherein the arm comprises a second arm comprising one end coupled to another end of the first arm, the second arm being configured to rotate on the horizontal surface relative to the first arm,

wherein the hand is coupled to another end of the second arm and configured to rotate on the horizontal surface relative to the second arm,

wherein the substrate transfer robot is configured to take a normal posture with the first arm, the second arm, and the hand supporting the at least one substrate superimposed over each other in plan view, and is configured to rotate within the minimal rotation area when the first arm rotates on the horizontal surface about the one end of the first arm as the center of rotation, and

wherein with the substrate transfer robot taking the normal posture, at least one distance among a first distance between the center of rotation of the first arm and a distal end of the first arm, a second distance between the center of rotation of the first arm and a distal end of the second arm, and a third distance between the center of rotation of the first arm and a distal end of the at least one substrate supported by the hand is larger than the distance between the center of rotation of the first arm and the second apparatus in plan view.

13. The substrate transfer system according to claim **12**, wherein the first distance, the second distance, and the third distance are approximately equal to each other, and each of the first distance, the second distance, and the third distance is larger than the distance between the center of rotation of the first arm and the second apparatus.

14. The substrate transfer system according to claim **13**, wherein when the substrate transfer robot transfers the at least one substrate from the first position in the first apparatus to the second position in the second apparatus, the substrate transfer robot is configured to fold the first arm and the second arm together and protrude the arm into the second apparatus through the opening.

15. The substrate transfer system according to claim **12**, wherein when the substrate transfer robot transfers the at least one substrate from the first position in the first apparatus to the second position in the second apparatus, the substrate transfer robot is configured to fold the first arm and the second arm together and protrude the arm into the second apparatus through the opening.

16. The substrate transfer system according to claim **15**, wherein the substrate transfer robot is configured to transfer the at least one substrate while keeping a center of the at least one substrate along an imaginary line that is approximately parallel to the second apparatus in plan view, when the substrate transfer robot folds the first arm and the second arm together and protrudes the arm into the second apparatus through the opening.

17. The substrate transfer system according to claim **1**,

wherein the substrate transfer robot comprises a height direction, and the hand and the arm are configured to move in the height direction,

wherein the first apparatus is configured to accommodate a plurality of substrates at different height positions in the first apparatus, and

wherein the opening is open from a first height position through to a second height position, the first height position corresponding to a position at which the hand and the arm support one substrate, among the plurality of substrates, that is at a lowest position among the different height positions in the first apparatus, the second height position corresponding to another position at which the hand and the arm support another substrate, among the plurality of substrates, that is at a highest position among the different height positions in the first apparatus.

18. The substrate transfer system according to claim **1**,

wherein the first apparatus comprises a third position farther from the substrate transfer robot than the first position in plan view,

wherein the substrate transfer robot comprises a height direction, and the hand and the arm are configured to move in the height direction within a movable range,

wherein the opening has a height range smaller than the movable range,

wherein the first apparatus is configured to accommodate a plurality of substrates at the third position, and

wherein when the substrate transfer robot transfers one substrate among the plurality of substrates at the third position, the substrate transfer robot is configured to pull the one substrate out of the first apparatus, and move the hand and the arm in the height direction so as to protrude the arm into the second apparatus through the opening.

19. The substrate transfer system according to claim **1**,

wherein the first apparatus includes the first side wall,

wherein the second apparatus includes the second side wall opposite to the first side wall to define the robot installment area between the first side wall and the second side wall,

wherein the minimal rotation area is defined about the center of rotation by at least one of the hand, the arm and the at least one substrate supported by the hand, and

wherein the substrate transfer robot is configured to take out the at least one substrate from the first apparatus so that the outer periphery of the minimal rotation area overlaps the inside of the second apparatus through the opening.

20. The substrate transfer system according to claim **1**,

wherein the second apparatus includes the first side wall and the second side wall.

21. The substrate transfer system according to claim **20**,

wherein the first side wall comprises a first opening, and

wherein the second side wall comprises a second opening.

22. A substrate processing system comprising:

a first apparatus including a plurality of cassettes disposed at different locations in the first apparatus and each configured to accommodate at least one substrate;

a second apparatus comprising an opening; and

a substrate transfer robot disposed in a robot installment area defined between the first apparatus and the second apparatus, the robot installment area including a plurality of side walls, the substrate transfer robot being configured to transfer the at least one substrate from each of the plurality of cassettes to the second apparatus via the opening, the substrate transfer robot comprising:

a base stationary relative to the robot installment area;

a hand configured to support the at least one substrate; and

an arm rotatably mounted to the base about a center of rotation to move the hand, the arm and the hand supporting the at least one substrate being configured to rotate on a horizontal surface within a minimal rotation area of the substrate transfer robot such that an outer periphery of the minimal rotation area overlaps an inside of the second apparatus through the opening so as to transfer the at least one substrate from a first position in any one of the plurality of cassettes disposed in the first apparatus to a second position in the second apparatus through the opening,

wherein the minimal rotation area is defined by a minimal rotation radius that is an outermost radius of the substrate transfer robot from the center of rotation when the substrate transfer robot is in a collapsed state,

wherein the minimal rotation radius is larger than a first minimum distance between the center of rotation and a first side wall of the plurality of side walls, and

wherein the minimal rotation radius is larger than a second minimum distance between the center of rotation and a second side wall of the plurality of side walls.

23. The substrate processing system according to claim **22**,

wherein the substrate transfer robot comprises a height direction, and the hand and the arm are configured to move in the height direction,

wherein the first apparatus is configured to accommodate a plurality of substrates at different height positions in the first apparatus, and

wherein the opening is open from a first height position through to a second height position, the first height position corresponding to a position at which the hand and the arm support one substrate, among the plurality of substrates, that is at a lowest position among the different height positions in the first apparatus, the second height position corresponding to another position at which the hand and the arm support another substrate, among the plurality of substrates, that is at a highest position among the different height positions in the first apparatus.

24. The substrate processing system according to claim **22**,

wherein the first apparatus includes the first side wall,

wherein the second apparatus includes the second side wall opposite to the first side wall to define the robot installment area between the first side wall and the second side wall,

wherein the minimal rotation area is defined about the center of rotation by at least one of the hand, the arm and the at least one substrate supported by the hand, and

wherein the substrate transfer robot is configured to take out the at least one substrate from the first apparatus so that the outer periphery of the minimal rotation area overlaps the inside of the second apparatus through the opening.

25. The substrate processing system according to claim **13**,

wherein the second apparatus includes the first side wall and the second side wall.

26. The substrate processing system according to claim **25**,

wherein the first side wall comprises a first opening, and

wherein the second side wall comprises a second opening.

27. A substrate transfer robot comprising:

a base stationary relative to a robot installment area defined between a first apparatus and a second apparatus comprising an opening, the robot installment area including a plurality of side walls, the first apparatus including a plurality of cassettes disposed at different locations in the first apparatus and each configured to accommodate at least one substrate;

a hand configured to support the at least one substrate; and

an arm rotatably mounted to the base about a center of rotation to move the hand, the hand and the arm being configured to transfer the at least one substrate from each of the plurality of cassettes to the second apparatus via the opening, the arm and the hand supporting the at least one substrate being configured to rotate on a horizontal surface within a minimal rotation area of the substrate transfer robot such that an outer periphery of the minimal rotation area overlaps an inside of the second apparatus through the opening so as to transfer the at least one substrate from a first position in any one of the plurality of cassettes disposed in the first apparatus to a second position in the second apparatus through the opening,

wherein the minimal rotation area is defined by a minimal rotation radius that is an outermost radius of the sub-

strate transfer robot from the center of rotation when the substrate transfer robot is in a collapsed state,

wherein the minimal rotation radius is larger than a first minimum distance between the center of rotation and a first side wall of the plurality of side walls, and

wherein the minimal rotation radius is larger than a second minimum distance between the center of rotation and a second side wall of the plurality of side walls.

28. The substrate transfer robot according to claim **27**,

wherein the first apparatus includes the first side wall,

wherein the second apparatus includes the second side wall opposite to the first side wall to define the robot installment area between the first side wall and the second side wall,

wherein the minimal rotation area is defined about the center of rotation by at least one of the hand, the arm and the at least one substrate supported by the hand, and

wherein the arm and the hand is configured to take out the at least one substrate from the first apparatus so that the outer periphery of the minimal rotation area overlaps the inside of the second apparatus through the opening.

29. The substrate transfer robot according to claim **23**,

wherein the second apparatus includes the first side wall and the second side wall.

30. The substrate transfer robot according to claim **29**,

wherein the first side wall comprises a first opening, and

wherein the second side wall comprises a second opening.

31. A substrate transfer system comprising:

a substrate transfer robot disposed in a robot installment area defined between a first apparatus and a second apparatus, the first apparatus including a plurality of cassettes disposed at different locations in the first apparatus and a first wall, the plurality of cassettes being each configured to accommodate at least one substrate, the second apparatus including a second wall opposite to the first wall to define the robot installment area between the first wall and the second wall, the substrate transfer robot being configured to transfer the at least one substrate from each of the plurality of cassettes to the second apparatus, the substrate transfer robot comprising:

a base stationary relative to the robot installment area;

a hand configured to support the at least one substrate; and

an arm rotatably mounted to the base to move the hand, the arm including a first arm rotatably mounted to the base at a first end about a center of rotation, the first arm having a second end rotatably connected to another component of the substrate transfer robot about an axis, the axis being a first point of articulation along the arm from the center of rotation to the hand, the first arm having a length longer than a minimum distance defined between the center of rotation and the first wall and a minimum distance defined between the center of rotation and the second wall in plan view.

32. The substrate transfer system according to claim **31**,

wherein the second wall includes an opening, and

wherein the center of rotation of the first arm is at a position that faces the opening in plan view, and the substrate transfer robot comprises a minimal rotation radius larger than a distance between the center of rotation of the first arm and the second apparatus.

33. The substrate transfer system according to claim **32**,

wherein the second wall is disposed at the second apparatus and approximately parallel to the first wall, and

wherein the center of rotation of the first arm is closer to the first wall than to the second wall in plan view, and the substrate transfer robot comprises a minimal rotation radius larger than a distance between the center of rotation of the first arm and the second wall.

34. The substrate transfer system according to claim **33**,

wherein the arm comprises a second arm comprising one end coupled to another end of the first arm, the second arm being configured to rotate on a horizontal surface relative to the first arm,

wherein the hand is coupled to another end of the second arm and configured to rotate on the horizontal surface relative to the second arm,

wherein the substrate transfer robot is configured to take a normal posture in which the first arm, the second arm, and the hand supporting the at least one substrate are superimposed over each other in plan view, and is configured to rotate within the minimal rotation area when the first arm rotates on the horizontal surface about the one end of the first arm as the center of rotation, and

wherein with the substrate transfer robot taking the normal posture, at least one distance among a first distance between the center of rotation of the first arm and a distal end of the first arm, a second distance between the center of rotation of the first arm and a distal end of the second arm, and a third distance between the center of rotation of the first arm and a distal end of the at least one substrate supported by the hand is larger than the distance between the center of rotation of the first arm and the second apparatus in plan view.

35. The substrate transfer system according to claim **34**, wherein the first distance, the second distance, and the third distance are approximately equal to each other, and each of the first distance, the second distance, and the third distance is larger than the distance between the center of rotation of the first arm and the second apparatus.

36. The substrate transfer system according to claim **34**, wherein when the substrate transfer robot transfers the at least one substrate from the first position in the first apparatus to the second position in the second apparatus, the substrate transfer robot is configured to fold the first arm and the second arm together and protrude the arm into the second apparatus through the opening.

37. The substrate transfer system according to claim **36**, wherein the substrate transfer robot is configured to transfer the at least one substrate while keeping a center of the at least one substrate along an imaginary line that is approximately parallel to the second apparatus in plan view, so as to fold the first arm and the second arm together and protrude the arm into the second apparatus through the opening.

38. The substrate transfer system according to claim **37**,

wherein the substrate transfer robot is configured to rotate the hand supporting the at least one substrate relative to the second arm from a state in which the hand supports the at least one substrate at the first position in the first apparatus so as to take a first intermediate posture in which the center of the at least one substrate is on the imaginary line,

wherein the substrate transfer robot is configured to move from the first intermediate posture while keeping the center of the at least one substrate along the imaginary line so as to change into a second intermediate posture in which the first arm and the second arm are folded together, and

wherein the substrate transfer robot is configured to move from the second intermediate posture so as to transfer the at least one substrate to the second position in the second apparatus.

39. The substrate transfer system according to claim 37,
wherein the second wall is disposed at the second apparatus and approximately parallel to the first wall, and
wherein the imaginary line is at approximately a same distance from the first wall and the second wall.

40. The substrate transfer system according to claim 34,
wherein the first apparatus is configured to accommodate a plurality of substrates at different positions in plan view, and
wherein the substrate transfer robot is configured to transfer any one substrate among the plurality of substrates in the first apparatus to the second position in the second apparatus such that with the one substrate partially beyond the opening, the first arm and the second arm are folded together and oriented in one direction that is approximately orthogonal to a direction that is from the center of rotation of the first arm to the second position in the second apparatus.

41. The substrate transfer system according to claim 31,
wherein the substrate transfer robot comprises a height direction, and the hand and the arm are configured to move in the height direction,
wherein the first apparatus is configured to accommodate a plurality of substrates at different height positions in the first apparatus, and
wherein the opening is open from a first height position through to a second height position, the first height position corresponding to a position at which the hand and the arm support one substrate, among the plurality of substrates, that is at a lowest position among the different height positions in the first apparatus, the second height position corresponding to another position at which the hand and the arm support another substrate, among the plurality of substrates, that is at a highest position among the different height positions in the first apparatus.

42. The substrate transfer system according to claim 31,
wherein the first apparatus comprises a third position farther from the substrate transfer robot than the first position in plan view,
wherein the substrate transfer robot comprises a height direction, and the hand and the arm are configured to move in the height direction within a movable range,
wherein the opening has a height range smaller than the movable range,
wherein the first apparatus is configured to accommodate a plurality of substrates at the third position, and
wherein when the substrate transfer robot transfers one substrate among the plurality of substrates at the third position, the substrate transfer robot is configured to pull the one substrate out of the first apparatus, and move the hand and the arm in the height direction so as to protrude the arm into the second apparatus through the opening.

43. A substrate processing system comprising:
a first apparatus including a plurality of cassettes disposed at different locations in the first apparatus and a first wall, the plurality of cassettes being each configured to accommodate at least one substrate;
a second apparatus including a second wall opposite to the first wall to define a robot installment area between the first wall and the second wall; and
a substrate transfer robot disposed in the robot installment area and configured to transfer the at least one substrate from each of the plurality of cassettes to the second apparatus, the substrate transfer robot comprising:
a base stationary relative to the robot installment area;
a hand configured to support the at least one substrate; and
an arm rotatably mounted to the base to move the hand, the arm including a first arm rotatably mounted to the base at a first end about a center of rotation, the first arm having a second end rotatably connected to another component of the substrate transfer robot about an axis, the axis being a first point of articulation along the arm from the center of rotation to the hand, the first arm having a length longer than a minimum distance defined between the center of rotation and the first wall and a minimum distance defined between the center of rotation and the second wall in plan view.

44. A substrate transfer robot comprising:
a base stationary relative to a robot installment area defined between a first apparatus and a second apparatus, the first apparatus including a plurality of cassettes disposed at different locations in the first apparatus and a first wall, the plurality of cassettes being each configured to accommodate at least one substrate, the second apparatus including a second wall opposite to the first wall to define the robot installment area between the first wall and the second wall;
a hand configured to support the at least one substrate; and
an arm rotatably mounted to the base to move the hand, the hand and the arm being configured to transfer the at least one substrate from each of the plurality of cassettes to the second apparatus, the arm including a first arm rotatably mounted to the base at a first end about a center of rotation, the first arm having a second end rotatably connected to another component of the substrate transfer robot about an axis, the axis being a first point of articulation along the arm from the center of rotation to the hand, the first arm having a length longer than a minimum distance defined between the center of rotation and the first wall and a minimum distance defined between the center of rotation and the second wall in plan view.

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